field within a horn or tube lined with an absorbent substance. The transmission of sound through fabrics, walls, and telephone booths may also be quickly examined. The instrument is used by psychologists and by telephone and acoustic engineers, and is of interest to navigators. An interesting by-product is an instrument for showing the direction of an acoustic signal in the fog. It has been called a phonotrope, on the analogy of heliotrope, which turns to the sun. It consists of two equal horns which bring the sound to the opposite sides of the disc. When the whistle blows, the band of light spreads out, and on turning the instrument it closes to zero when the sound is directly ahead. Thus at several miles the direction is given to within two or three degrees.

Finally, let us consider that mystery of sound, the violin, which has been studied by Prof. Barton of Nottingham, and by Prof. Raman at Calcutta. This may be described by the engineer as a box of curious shape, made of a curious substance, wood, of variable thickness, with two holes of strange figure to let the sound out of the resonating box. The latter is actuated by a curious substance, catgut, made of the intestines of a sheep, and set in vibration by another curious substance, the tail of a horse. Yet from this wonderful box we get the most ravishing sounds, which affect profoundly the emotions of the most civilised. Yet the physicist reduces all musical instruments to combinations of resonators with strings, membranes, bars, plates, and horns. The mathematical theory of strings was given by Euler two hundred years ago, of bars and plates less than a hundred years, of resonators by Helmholtz and Rayleigh, and I have recently added a theory of horns which, while only approximate, works well in practice, and investigations are now being carried out by such methods on vowels and the violin.

Biological Studies in Madeira.

By Dr. Michael Grabham.

The component islands and rocks on the Madeira Archipelago are separate foci of volcanic ejecta in the abysmal oceanic depths, and the level of the Atlantic waters might be lowered 100 fathoms without merging them in a common connexion. Of the 170 forms of Testacea existing in the region, only five species are distributed throughout the Island group, and such evidence is adversely copious and conclusive as to the theory that the Madeiras are a surviving relic of a former continent.

The fossil shells now lifted 1500 ft. above the sea level show an upper Miocene association, but the massive piling up of volcanic matter in countless reiteration of eruption and age-long intermission began long before the fossil shells were living creatures on a Miocene shore.

Examination of a fossil leaf-bed, containing examples of the specific insular flora buried 120 ft. beneath a variety of strata and capped by a thick deposit of white trachyte, shows that the trachyte rock has almost disappeared under the slowly working forces of erosion and disintegration. From this is adduced the enduring quality of the trachyte steps and gateways of Funchal, which have been exposed for two centuries, with little evidence of decay, to the same influences under which the thick leaf-bed cap has vanished. Thus we need set no niggardly limit to the time requirement for the establishment of the specialised forms of life developed and buried ages before the trachyte capped the successive strata in a flowing stream of lava.

The Archipelago came to us 500 years ago, in the dawn of navigation, ready made, already well worn into characteristic scenery, with the local flora stabilised, the discovery being due to the erratic drifting from its course to the West African coast of a crazy vessel of Prince Henry the Navigator. An ancient building is regarded locally as the traditional home of Christopher Columbus, who married the Admiral Peristrello's daughter, and was, no doubt, inspired for his western enterprise by watching the sea currents and the evidence they brought of land and life beyond the horizon.

The agencies of transport and distribution we know; the sea currents are the same; the same winds prevail; the same birds come and go, though it may be difficult to believe that the presence of the Testacea in 170 forms and the Coleoptera in 700 species has been due to fitful and accidental influences. It is difficult, though the rain falls now as formerly, to point to a single rock or ravine as having appreciably lessened or deepened, though the storms of every winter carry thousands of tons of material to the ocean bed.

The completeness with which the natural orders exist in Madeira and the prevalence of specific forms make it less bewildering to believe that these forms of life were brought to us in pots from the Garden of Eden than to trace their descent from primeval forms which no longer survive. The shells can be compared with fossilised ancient types, but the flora has no such satisfactory appeal.

The name "Madeira" is derived from the hard wood known as Materia; Coniferæ are not prominent in the native flora. I have introduced *Pinus Insignis*, *Cupressus Macrocarpa*, and other species, while the seeds of *Persea Indica* have been sent abroad with the view of enlarging the range of the alligator pear-tree by grafting.

In conformity with other oceanic centres, Madeira has numerous examples of orders with a single genus and of genera with a single species. The striking fruticose echiums illustrate stabilised specific forms, and show how a new bee has effected an important hybridisation by which perennial characters were conferred on a plant of biennial life-limit, the helicoid flowering cymes, normally 2½ inches long, being prolonged into growths 7 or 8 feet high.

The Carniolan bee concerned in this hybridisation at first abstained from fruit eating, but it speedily blended with the local black bee and became a vineyard pest. Similarly many attractive flowers have become in Madeira pernicious pests; such are Oxalis, Eupatorium, Senecio, and *Freezia refracta.*

Madeira could, however, be made a focus for the dissemination of plants of economic value. The gourd, *Sechium Edule,* has remarkable food value, and is very potent in fat utilisation. The plant shows a singular development of the seed-surrounding flesh into the permanent stem growth of the climbing plant. During the stress of war, when German U-boats wantonly destroyed everything and the Island food was restricted to local resources, the potency of the Sechium was realised, and on several occasions the sullen apathy of incipient starvation was awakened into reviving animation under its influence. The gourd was also utilised during the time of construction of the Panama Canal, when the Italian labourers had to be coerced to use a sufficient fat ration in their food in order that they might equal the output of their Canadian fellow-labourers.

Another valuable plant is *Lycopersicum cerasiforme,* which provides an agreeable tomato food with important antiscorbutic qualities. In the Salvage Islets there is also *Monizaa Edulis,* the carrot fern of Madeira, with a species of the apterous Deucalion, otherwise known only on the Madeira rocks, side by side with the Canarian *Samphire astadamya*; this seems to establish a balancing correlation or agreement between the botanic and entomological features of the two island groups.

An interesting illustration of sterility yielding to the introduction of a new pollen is afforded by a species of the Bignoniaceous jacaranda, while the sterility of the banana and the complete loss of fertility in the fruiting *Solanum guatemalense* show, on the other hand, how we are constantly curbing the superabundant seed growth of valued sub-tropical fruits, such as the custard apple and the loquat, which in the fruit-vacant months of Northern Europe should flood British markets both in perfection and profusion.

Many introduced plant pests, such as Peronospera and Oidium, have been brought under control, and even the *Phylloxera vastatrix,* which destroyed the Madeira vineyards before its life-history was made out, has become almost negligible in its depredations; thus the wine of Madeira has returned in adequate and superabundant supply. The Argentine ant may be credited to some extent with restraining the activity of the Phylloxera aphis. In view of the almost certain invasion of the British Islands by this pest, the Board of Agriculture should issue and circulate the American official booklet on the subject, together with a reprint of a paper read by me before the British Association two years ago. No less than 47,000 of these ants have been found engaged in draining a single lemon tree of its vitality; but various agencies of restraint are now employed in the orange and coffee plantations. The common flea and the house-fly do not seem to have abated under the domination of the Iridomyrmex.

The winged ant-queens suffer deälation after mating, and, discarding the cares of motherhood, they issue forth with the workers and found new colonies wherever conditions invite. The intelligent ingenuity of the ant and its tenacity of purpose in the face of obstacles is very remarkable.

As regards oceanic research, organised exploration of the ocean flora and deep-water biology is urgently necessary in the national interest. This investigation is a part of our responsibility in Imperial expansion; a second *Challenger* expedition is long overdue, and could be accomplished at a comparatively small cost.

The fisheries of Madeira provide several novel specimens. The Sherny, *Polyprion Cernier,* freshly brought from the deep sub-tropical water of the Madeira district, is typical of the warmer seas, though occasionally seen farther north. This is the wreck fish of British nomenclature, so known from its association with floating timber logs. The early life of the fish is passed in the sunlit surface waters, but the proper habitat of the full-sized creature, 100 lbs. in weight or more, is in the open sea at the enormous depth of 2000 or 3000 ft.

The fish, when brought to the surface from that profound depth, so distends at the removal from the vast pressure below that it emerges from the water like a cork or bladder, with its stomach forced through the capacious mouth and the eyes protruding in front of their sockets. No explanation is known of the conditions which prompt the fish to descend from the surface warmth into the cold darkness of the abysmal region, where only the larger examples are to be found. That the sea is nowhere azoic is shown by the plump and well-fed condition in which the Sherny comes to the surface. Its dull colouring, which is shared by the Aplurus and *Promethus Atlanticus,* contrasts surprisingly with the brilliant hues of Sebastes, Scorpœna, and Lampris, which also live in the depths, though rarely in close association with their sober-tinted brethren. The Sherny has a large air-bladder firmly attached to the spine, but knowledge of the function of this organ is very imperfect. The regulation of submersibility by a voluntary act of filling, emptying, or compressing is probably only a subordinate physiological function, for the structure of the bladder is suggestive of pulmonary functions, and its firm attachment to the spine and its prolongation upwards to a cerebral connexion with the organ of hearing, seem a sure indication of the use of the organ as a resonator in the interpretation of weak sonorous vibrations. The air-bladder, nevertheless, is totally absent from the Aplurus and many other fishes.

Some of the fishes swimming near the surface are believed to have their air-bladders charged with nitrogen, but extensive observation does not confirm the current idea that in deep water oxygen is the inflating gas. The consumption of oxygen by fish is small, and the standard of respiration in oceanic fish of deep water is low; the heart-beat in the Polyprion will continue many hours after every other sign of life has ceased. Stationary traps are necessary for the investigation of the abysmal forms of life.

The surface plankton is abundant, but the contracted empty stomachs of some of the deep-sea fish is evidence against the idea that much food is dissolved in deep-sea water. The *Aphanopus Carbo* is a voracious monster which abounds in the lesser depths, and ranges freely among the inexhaustible invertebrates of those regions.

During a series of observations on earth-currents in deep-sea cables, strange effects were noted which were found to be due to a submarine earthquake which broke up many miles of the ocean floor. The occurrence may be compared with a similar commotion which destroyed an important fishery in the sub-tropical waters of the United States.

A full and comprehensive appreciation of sub-tropical ichthyology is necessary to indicate the vast and interesting variety of the fauna and the intrinsic charm of scientific research. It is the duty and interest of the community to discover the potential genius and place him where he can accomplish that for which he is fitted, unfettered by the suppressing restrictions of a false communistic socialism or cramping of individual effort.

Magna opera Domini exquisitae omnes
voluntates ejus.

Ten Years of X-ray Crystal Analysis.

By Dr. A. E. H. Tutton, F.R.S.

A SPECIAL number of *Die Naturwissenschaften*, entitled "Zehn Jahre Laue-Diagramm," was issued on April 21, forming Heft 16, 1922, which contains eight articles by authors who have contributed to the subject of X-ray analysis on the continent since its first inception by Dr. M. von Laue, among whom may be mentioned Drs. Friedrich and Knipping, who collaborated with Dr. von Laue in the first discovery, Prof. Debye, and Prof. Niggli. Probably the article of deepest interest to the general reader will prove to be that of Dr. Friedrich, who gives an account of the circumstances in the year 1912 in Munich when the first discovery was made. To the present writer, who was himself in Munich in the summer of that same remarkable year, this memoir is of fascinating interest. It has to be remembered that the scientific coterie at that time forming the professorial staff of the University, Museum, and Institute, included Prof. Röntgen, the generally recognised discoverer of X-rays (although their production had for some time previously been almost a daily occurrence in the private laboratory of the late Sir William Crookes); Prof. von Groth, the founder and editor of the *Zeitschrift für Krystallographie* and the doyen of crystallographers, whose brilliant lectures on crystal structure and optics attracted students from all over the world; Prof. Sommerfeld, who had carried on the tradition of X-ray physics bequeathed to him by his predecessor Boltzmann, and also extended the work of Haga and Wind, and of Walther and Pohl on X-radiograms and the general physics of X-rays; Prof. Ewald, who had studied the behaviour of long electromagnetic waves with space-lattices; and Dr. von Laue, who had specialised largely on the interference phenomena of ordinary optics. It was among this strong combination of crystallographers, X-ray specialists, and diffraction (grating) opticians that the inception of the attack on crystals by X-rays had its birth.

During a conversation between Laue and Ewald, the former raised the question as to how electromagnetic waves would behave which were small compared with the grating constants, and from his optical experience he suggested that diffraction spectra should be produced. The order of the space-lattice cell dimensions of crystals was already known to be about an Ångström unit (10^{-8} cm.), from the density and molecular weight of the crystal and the mass of a hydrogen atom. The work of Sommerfeld and of Walther and Pohl had led us to expect that the order of dimensions of the wave-length of X-rays would be about one-tenth of this (10^{-9} cm.). Consequently Laue suggested that the conditions should be particularly favourable for the origination of interference phenomena on the passage of X-rays through crystals.

The discussion was continued in the common room, and taken up by the whole, deeply interested coterie, and Friedrich, who was at the time acting as Sommerfeld's assistant, declared himself, with youthful enthusiasm, ready to test the idea practically. He secured the assistance of Knipping, who had more spare time at his disposal, and together they set up the now famous arrangement of X-ray bulb, leaden screens with slits for ensuring the exit of a definite beam of X-rays, simple goniometer carrying the crystal, and photographic plates to receive the expected radiations. At the first attempt the sensitive plates were only arranged parallel to the primary beam of X-rays, as any effect expected appeared likely to be of the character of secondary rays from the crystal, and it was only on repeating the exposure with a photographic plate arranged behind the crystal, perpendicular to the direct beam, that the first Laue radiogram with a crystal of zinc blende was obtained, after several hours of exposure.

Friedrich describes how excited and delighted he was when, alone in his working room at the Institute late that night, he saw the spots appear on the plate under the influence of the developer, due to the deflected X-rays, now known to be reflected from the planes of atoms within the crystal, the planes of the atomic space-lattice. Next morning he went early to show the negative to Knipping, and together they hastened to Laue and Sommerfeld, who were both naturally equally interested and delighted. Prof. Sommerfeld at once excused his assistant from his ordinary duties, so that he might go ahead with further experiments. Both Profs. von Groth and Röntgen, to whom the result of the experiment was at once communicated, supplied materials and gave valuable advice. A much better and more accurate apparatus was erected, including a good goniometer for the exact adjustment of the crystal (which is particularly necessary), and the excellent X-radiograms of zinc blende, quartz, rock-salt, and other crystallised substances, now so well known were obtained as the immediate results.

Dr. Knipping directs special attention in his article to the remarkable work of Siegbahn, who worked with an evacuated apparatus, so as to exclude air absorption of the X-rays, and measured the wave-lengths of the "softer" long wave-length portion of the radiation, eventually discovering and measuring rays as long as ten Ångström units. Compton, it will be remembered, at the other extreme, has measured X-rays (γ-rays